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Instrumentation & Control
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Inglewood, Calif. 90301

INSTRUCTION MANUAL

kepco®

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kepco

INSTRUCTION MANUAL

VOLTAGE REGULATED POWER SUPPLY

MODELS SC 18-4 AND
SC 18-4M*

SERIAL NO. C-25560

SECTION A. SPECIFICATIONS AND DESCRIPTION

A-1. ELECTRICAL AND PHYSICAL SPECIFICATIONS.

....DC OUTPUT VOLTAGE:
0-18 volts, continuously variable.

....DC OUTPUT CURRENT:
0-4 amperes, continuous duty.

....AC INPUT:
105-125 volts, 50-65 cps; 3.0 amperes maximum, at 125 v ac, 60 cps.

....REGULATION:

- LINE: Less than 0.1% for 105 to 125 v line voltage change, at any output voltage setting in the specified range.

- LOAD: Less than 0.1%, or 0.003 v whichever is greater, for 0 to 4 amperes load change, at any output voltage setting in the specified range.

....RECOVERY TIME:
50 microseconds. Defined as the time required for the output voltage to return to within 0.1 v of the output voltage setting.

....OUTPUT IMPEDANCE:
DC to 100 cps: less than 0.005 ohm; 100 cps to 1 KC: less than 0.01 ohm; 1 KC to 100 KC: less than 0.08 ohm + 1 μh

....RIPPLE:
Less than 0.001 volt, rms.

....STABILITY:
Output voltage drift less than 0.1% or 0.006 v whichever is greater, at constant ambient temperature over a period of 8 hours after the supply has reached equilibrium. Drift is less than 0.5% during warm-up following a "cold" start, (approximately 3/4 hour) before supply reaches equilibrium.

....AMBIENT OPERATING TEMPERATURE:
-20C to +50C.

....TEMPERATURE COEFFICIENT:
Output voltage changes less than 0.05% per degree C change.

....METERS:
Furnished on units with suffix "M" following Model No.
Voltmeter 0-20 volts, 2-1/2".
Ammeter 0-4 amperes, 2-1/2".

....STORAGE TEMPERATURE:
-40 C to +85 C.

....DIMENSIONS:
Height 3-1/2"; Width 19", Depth 13".

....COLOR:
Kepco Standard Gray Hammertone.

....SHIPPING WEIGHT:
43 pounds, approximate.

A-2. TERMINALS AND CONTROLS -

- ON FRONT PANEL.

....POWER ON-OFF SWITCH and PILOT LIGHT.

....INPUT POWER FUSE.

....DC OUTPUT AND GROUND TERMINALS. Binding posts, clearly marked. The output terminals are isolated from the chassis, either Positive or Negative terminal may be grounded. Note: The chassis is connected to the third, or ground pin (green wire) of the power line-cord.

....VOLTAGE CONTROL. One-turn continuously variable, for setting the output voltage.

- ON REAR PANEL.

....BARRIER TERMINAL STRIP. Barrier type terminal strip with nine screw terminals provides addition connection the DC Output and Ground, and connecting terminals for Remote Error Sensing, Remote Voltage Control and Current Regulated Operation. (See "Special Features" Section A-3, and Section C, of this Manual)

....CURRENT LIMIT CONTROL. Screwdriver adjustment accessible through labelled opening provided on rear panel, for setting the value to which the output current will be limited. (See "Special Features" Section A-3)

A-3. SPECIAL FEATURES

....OVER-TEMPERATURE PROTECTION. In the event an over-temperature condition develops, a thermostat relay turns the DC Output off. (The fan motor will continue operating). The relay is reset and DC Output restored, after the unit has cooled, by turning the Power Switch off, and then on.

....OVERLOAD PROTECTION. The maximum output current is automatically limited to a factory pre-set amount equal to 120% of the maximum rated output current of the supply. This allows operation into a sustained overload up to full short-circuit. Output voltage restores when the overload is removed.

....CURRENT LIMIT ADJUSTMENT. An adjustable output current limiting control is provided, separate from the factory set maximum current feature. The limiting circuit may be adjusted with this control to automatically limit the output current to any value from 10to 120% of the maximum rated output of the supply. (See Section C)

....REMOTE ERROR SENSING. Terminals are provided for sensing the regulated output voltage directly at the load, by-passing, and thus eliminating the effect on regulation, of any voltage drop in the connecting leads between the output terminals and the load. (See Section C)

....REMOTE VOLTAGE CONTROL. Terminals are provided for the connection of an external Voltage Control in place of the internal Control, for remote control adjustment of the output voltage. The ratio of Control resistance to the voltage that is to be controlled remotely, is 1000 ohms per volt above zero; e.g., for remote control 0-18 volts, Control resistance required=0-18 K. (See Section C)

....CONSTANT CURRENT OUTPUT. This supply may be adapted to provide Regulated Current output, by connecting two resistors externally to terminals provided, and without requiring internal modification to the unit. (See Section C)

DC Output Characteristics, Regulated Current Operation.
Current: 0.01 ampere to maximum rated output.
Voltage: 0 to maximum rated output (volts).
Regulation: Line, 0.1% for 105-125 line voltage change.
Load, 0.2% for minimum to maximum load change.

SECTION B.

THEORY OF OPERATION

This power supply is of a servo or closed loop design in which the pass elements are in series with the load. (See block diagram B-1).

The voltage drops in the closed loop system are automatically adjusted according to the comparison of a sample output voltage with the reference voltage in the CONTROL UNIT. The differential product of this comparison is amplified and fed back as the ERROR INPUT to control the voltage drop across the pass transistors. The ERROR INPUT to the PASS CIRCUITRY is a negative or degenerative feedback signal. Consequently, the voltage drop across the pass transistors is such as to oppose output voltage change.

CAPITALIZED TERMS ADOPTED FOR FOLLOWING OUTLINE AND DISCUSSION REFER TO DESIGNATIONS ON THE CIRCUIT SCHEMATICS IN THE REFERENCE INDEX.

I. POWER UNIT (Circuit Schematic Tile)

A. INPUT CONTROL CIRCUITRY - Controls power input from the line to the DC SOURCES.

B. DC SOURCES - Provide main and auxiliary rectified power for all DC circuitry.

C. PASS CIRCUITRY - In the MAIN DC path to the output. All current drawn by the load goes through the pass elements, hence the name.

II. CONTROL UNIT (Circuit Schematic Tile)

A. REFERENCE VOLTAGE CIRCUITRY - Maintains a stable voltage standard for the comparison circuitry.

B. THE COMPARISON AMPLIFIER - Functions as the "error sensing" and cascade amplification circuit.

III. COMPARISON BRIDGE -

Consists of elements in both the POWER UNIT and CONTROL UNIT in a circuit configuration which effects a comparison between an output voltage sample and a stable reference voltage.

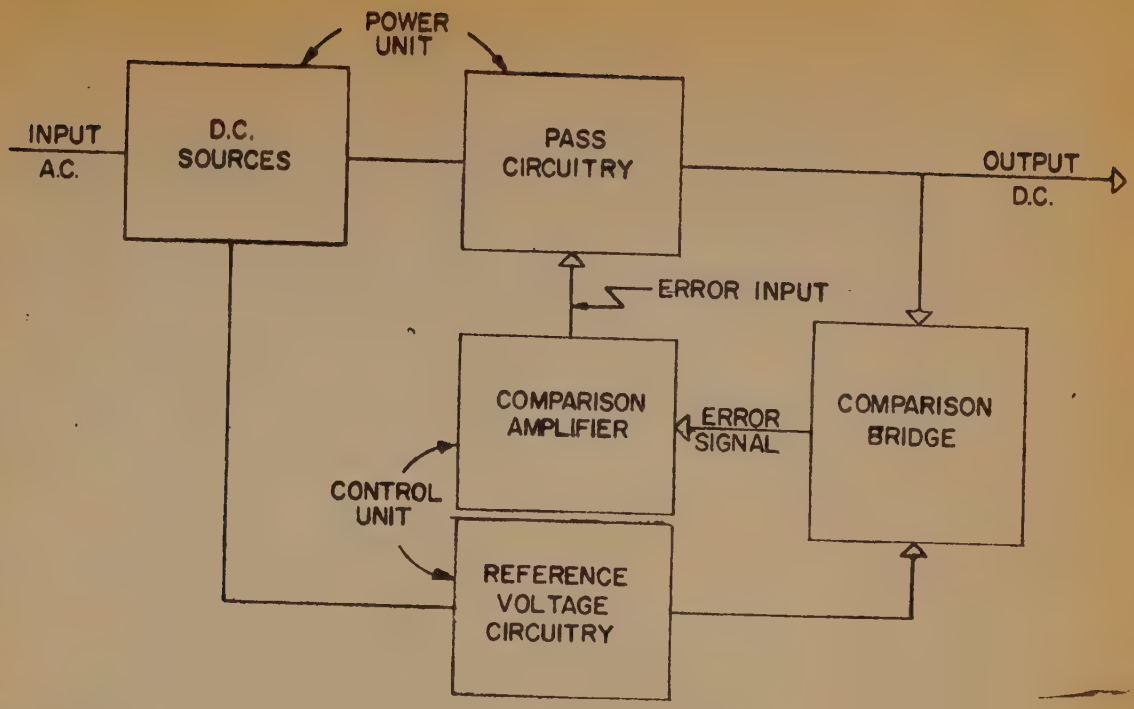


DIAGRAM B-1

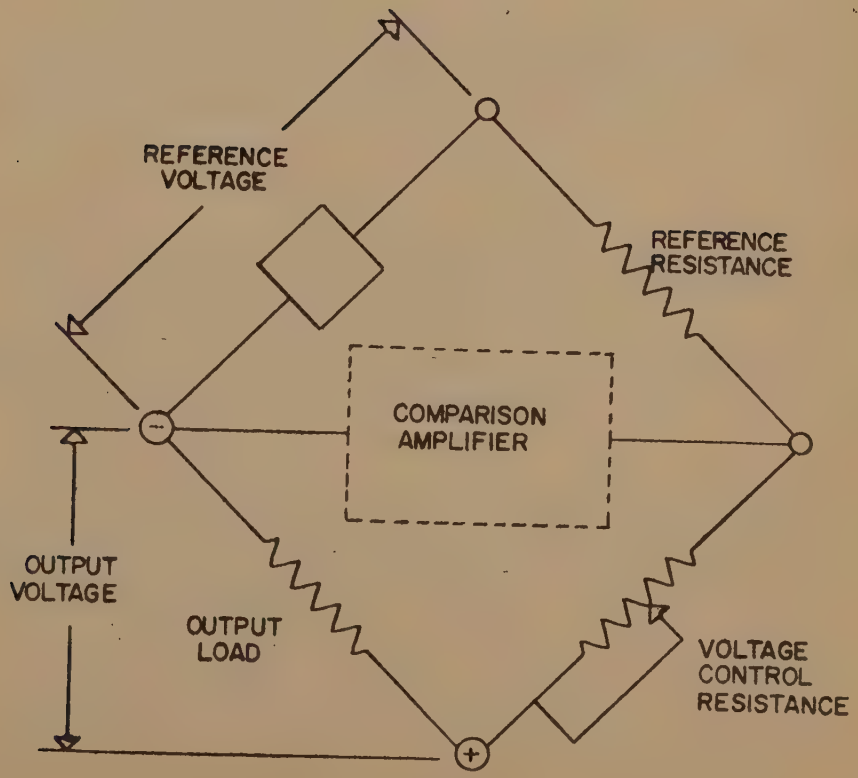


DIAGRAM B-2

NOTE:

The following discussion describes the elements of the foregoing outline in greater detail. As before, capitalized terms refer to designations on the schematic diagrams. Some of this discussion is of a general nature and may not apply in every detail to this specific model. Variations in the basic outline occur primarily in connection with the PASS CIRCUITRY INPUT CONTROL CIRCUITRY or the REFERENCE VOLTAGE CIRCUITRY and reflect design considerations relevant to the particular output requirements of the model. It should not be assumed that a set of circuit schematics is incomplete because it does not include all of the reference nomenclature used in this discussion.

.....I. POWER UNIT

A. INPUT CONTROL CIRCUIT:

(1) With the input switch closed, a forward bias on one semiconductor diode in the ENERGIZING CIRCUIT will draw a charging current for the capacitor which energizes the INPUT RELAY coil closing the input to the DC SOURCES transformers. As soon as the INPUT RELAY is closed, the DC in the input control circuit circulates through the thermal relay and input relay coil, bypassing the charged capacitor and holding the relay closed.

(2) If the pass element containing the thermostat control becomes overheated, the thermal switch opens the DC path to the INPUT RELAY de-energizing the relay coil and cutting off the input to the DC SOURCES.

NOTE:

The AC line power must be interrupted in order to reset the input relay after the thermal switch has opened the input to the DC SOURCES. Once the capacitor in the ENERGIZING CIRCUIT is charged, it cannot hold the relay when the thermal switch opens. This action tends to prevent damage to the pass elements from overheating in case the transistor associated with the thermostat dissipates heat faster than the other pass elements.

(3) When the input relay is opened by the action of the thermal switch or by pulling the line cord, the DISCHARGE RESISTOR effectively shorts the MAIN FILTER CAPACITOR preventing overvoltage surges.

NOTE:

For Models SC 18-4, SC 36-2 and SC 3672-1 substitute the following paragraph for section I-A.

These models employ a slightly different turn-on circuit - refer to schematic diagram.

....I. POWER INPUT

A. INPUT CONTROL CIRCUIT:

(1) INPUT RELAY automatically interrupts the power input to the DC SOURCES whenever the thermostat control detects overheating in the PASS CIRCUITRY. When it is thrown in response to an over-temperature condition, it provides a discharge path for the MAIN FILTER capacitor.

(2) OVERVOLTAGE RELAY provides a discharge path for the MAIN FILTER capacitor whenever the line input is interrupted.

(3) DISCHARGE RESISTOR - When the input to the DC SOURCES is opened by interrupted line power or the action of the thermostat control, the DISCHARGE RESISTOR effectively shorts the MAIN FILTER capacitor. This prevents overvoltage surges.

B. DC SOURCES:

(1) RETURN SUPPLY (full wave rectified and filtered) - provides a return path for leakage current (I_{CO}) from the pass transistors.

It is also a bleed path which provides a minimum operating current for the emitters of the pass transistors, enabling them to continue to remain operative or "sensitive" to the ERROR INPUT when the load current becomes zero or vanishingly small.

(2) MAIN SUPPLY (full wave rectified and filtered) - provides MAIN DC for the output, subject to the regulatory action of the PASS CIRCUITRY. The MAIN DC path includes the pass elements and the load in series.

(3) I_{CO} SUPPLY (full wave rectified) - Provides a supply of current to prevent spurious biasing of the pass transistors by collector leakage current (I_{CO}). I_{CO} generated as a function of temperature and flowing oppositely to the emitter base current tends to alter the ERROR INPUT unless this compensating supply provides bias stabilization.

(4) COLLECTOR SUPPLIES (negative half-cycle rectified) - provide proper collector bias for the PRE-DRIVERS.

C. PASS CIRCUITRY:

The power transistors which function as pass elements may be regarded as electronic variable resistors (or variable conductors) controlled or "varied" by an amplified ERROR INPUT. The amount of current "passed" by these transistors is a function of the magnitude of the forward conducting emitter-base bias. Since the ERROR INPUT is applied to the base terminal, a negative input will aid the forward conducting bias of a PNP transistor while a positive input will reduce the forward conducting bias. In response to the polarity and magnitude of the ERROR INPUT, the pass transistors control the current and voltage distribution in the MAIN DC loop and effect a constant output voltage.

Two main classifications of pass transistors may be indicated on the schematic acoording to the way in which they are driven:

(1) DRIVEN PASS - "driven" by the ERROR INPUT from the CONTROL UNIT. A DRIVER and a PRE-DRIVER may be connected in cascade with the DRIVEN PASS. These amplification stages increase the response and sensitivity of the system to output voltage changes. The DRIVEN PASS may be a single series pass transistor

or a series pass group of transistors connected in parallel for increased current capacity.

(2) SLAVE PASS - found in transistorized units requiring more than one series pass group in the MAIN DC path. These pass transistors "slavishly" follow the response of the DRIVEN PASS to the ERROR INPUT. The SLAVE PASSES are driven through a SLAVE VOLTAGE DIVIDER which effects an approximately equal voltage division among the series pass groups in models where the voltage range requires more than one group of series pass elements. The SLAVE PASSES may or may not have preliminary amplification stages in cascade.

When series pass groups contain transistors connected in parallel, an EQUALIZING RESISTOR is associated with each transistor. These EQUALIZING RESISTORS, tied to each emitter, provide a means of compensation for intrinsic differences among transistors within a pass group.

The expression "drop voltage" is sometimes used to describe the amount of voltage drop required of the pass elements to bring the COMPARISON BRIDGE into balance. This is the difference between the input and the desired output. True balance or stability is inherently impossible in a servo system, but the unbalance may be reduced to as small a magnitude as desired in a dynamically corrective system.

II. CONTROL UNIT

A. REFERENCE VOLTAGE CIRCUITRY:

The function of the REFERENCE VOLTAGE CIRCUITRY is to maintain a precise, stable voltage for the COMPARISON BRIDGE. This is normally achieved according to the model CONTROL UNIT with either of two basic design approaches:

(1) A CASCADE ZENER REFERENCE, consisting of Zener diodes of succesively decreasing values in cascaded stages each of which produce an increasingly regulated reference voltage. In practice, usually only two stages are used so that in effect the first Zener diode is a regulator for a voltage reference diode.

(2) Balanced amplifier regulation - Any disparity between the bases of the transistors in the set of 1st BALANCED AMPLIFIERS is coupled to the set of 2nd BALANCED AMPLIFIERS. The 2nd BALANCED AMPLIFIERS couple this amplified "error signal" to a REFERENCE DRIVER and a REFERENCE PASS which regulate the current through a REFERENCE DIODE in a manner analogous to the action of the PASS CIRCUITRY in the POWER UNIT.

B. COMPARISON AMPLIFIER CIRCUITRY:

(1) The COMPARISON AMPLIFIER consists of a series of cascaded transistor amplifiers which boost the "error input" to a sufficient level to drive the PASS CIRCUITRY in the POWER UNIT.

(2) The COMPARISON AMPLIFIER is connected across the COMPARISON BRIDGE from the junction of the VOLTAGE CONTROL and the REFERENCE RESISTANCE to the junction of the Zener reference diode and the negative output terminal. (See Diagram B-2). This arrangement is similar to that of the null galvanometer across a Wheatstone bridge. The unbalance in the COMPARISON BRIDGE is detected and amplified by the COMPARISON AMPLIFIER CIRCUITRY beginning a chain of circuit responses which produce an ERROR INPUT signal of proper phase and magnitude to effect corrective action by the pass circuitry.

III. Comparison Bridge:

(1) This bridge circuit implements the comparison between the OUTPUT VOLTAGE and the REFERENCE VOLTAGE. The signal produced by the comparison drives the COMPARISON AMPLIFIER CIRCUITRY.

(2) The Comparison Bridge is represented schematically in Diagram B-2.

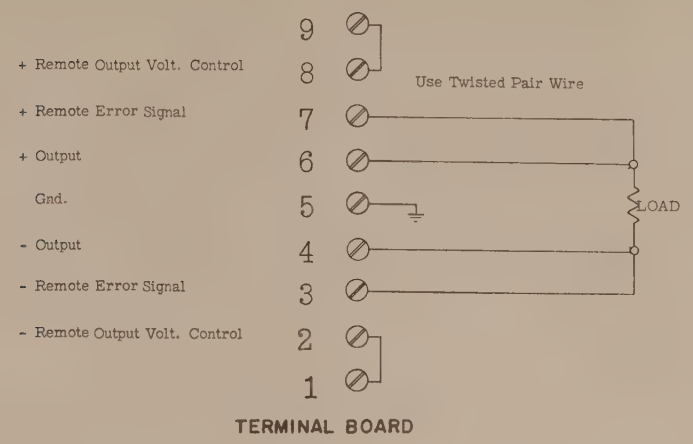
(3) Balance occurs in the Comparison Bridge when the following ratios are equal:

$$\frac{\text{Output Voltage}}{\text{Voltage Control Resistance}} = \frac{\text{Reference Voltage}}{\text{Reference Resistance}}$$

(4) When the Comparison Bridge is unbalanced by a decreasing output voltage drop across the load, it gives rise to a negative bias at the base of the COMPARISON FOLLOWER in the COMPARISON AMPLIFIER CIRCUITRY. This signal, amplified, acting as the ERROR INPUT negatively biases the base of the DRIVEN PASS, aiding its forward conducting bias and increasing the output voltage.

(5) A bridge unbalance caused by an increasing output voltage produces, of course, a chain of oppositely biased circuit responses which reduce the voltage across the load.

CONVERTING TO REMOTE ERROR SENSING



PROCEDURE:

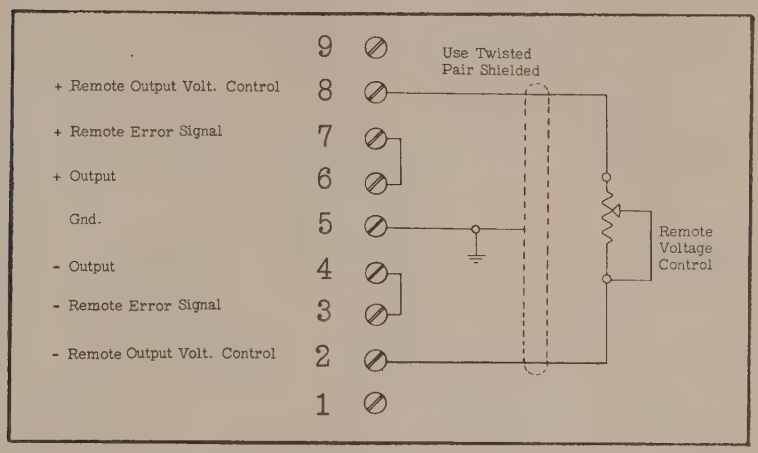
1. With AC input disconnected, remove jumper between POSITIVE OUTPUT and POSITIVE REMOTE ERROR SIGNAL (terminals 6 and 7) between NEGATIVE OUTPUT and NEGATIVE REMOTE ERROR SIGNAL (terminals 4 and 3) on rear terminal strip.

2. Using twisted pair wire, connect sensing leads from POSITIVE REMOTE ERROR SIGNAL (terminal 7) and from NEGATIVE REMOTE SIGNAL (terminal 3) to the load, observing polarities.

3. Using twisted pair wire, connect load supply leads from POSITIVE OUTPUT (terminal 6) and NEGATIVE OUTPUT (terminal 4) to the load.

NOTE: In operations requiring remote error sensing, voltage drops across the load supply leads will change the effective setting of the maximum current adjustment and possibly worsen regulation. By setting the MAXIMUM CURRENT ADJUST on the CONTROL UNIT it is possible to compensate for this effect for up to a maximum drop of 1/2 volt across the negative load supply lead. The 1/2 volt limit is imposed by the fact that this drop reduces the maximum forward conducting bias on the series pass transistors. The input base bias to the pass transistor is limited by the factory setting of the MAXIMUM CURRENT ADJUST. Consequently to avoid a deterioration in the ability of the pass transistors to follow the ERROR SIGNAL feedback and correct the output voltage, the following steps should be taken:

1. Turn CURRENT LIMIT ADJUST (if provided) to maximum clockwise position.
2. Load the power supply with the remote resistance necessary to draw slightly more than 120% of the maximum rated supply current at the indicated supply output voltage.
3. Turn MAXIMUM CURRENT ADJUST clockwise until output current reaches 120% of maximum rating.



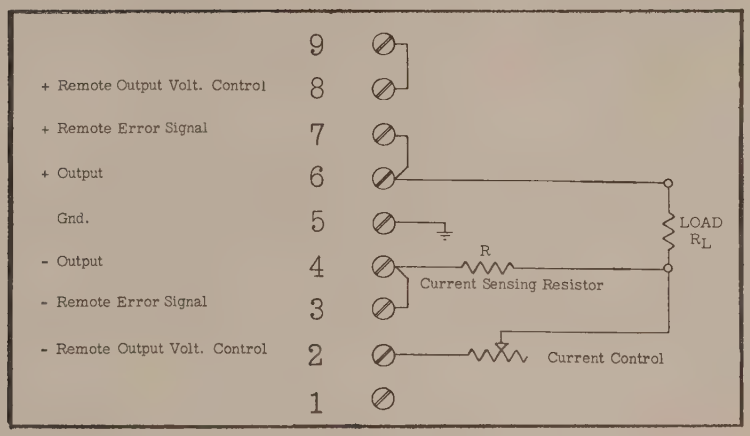
TERMINAL BOARD

PROCEDURE:

1. The REMOTE VOLTAGE CONTROL resistance, fixed or variable, should be equal to the product of the desired output voltage and the ohms per volt ratio specified for this model. (See discussion on REMOTE OUTPUT VOLTAGE CONTROL terminals in Section A).

2. With AC power disconnected, remove jumper between POSITIVE REMOTE OUTPUT VOLTAGE CONTROL (terminal 8) and terminal 9, and jumper between NEGATIVE REMOTE OUTPUT VOLTAGE CONTROL (terminal 2) and terminal 1.

3. Connect shielded twisted pair wire leads from POSITIVE REMOTE OUTPUT VOLTAGE CONTROL (terminal 8), and from NEGATIVE REMOTE OUTPUT VOLTAGE CONTROL (terminal 2) to REMOTE VOLTAGE CONTROL resistance. REMOTE VOLTAGE CONTROL, if variable, should be connected so that clockwise rotation increases resistance.



TERMINAL BOARD

PROCEDURE:

1. Remove jumper between NEGATIVE REMOTE OUTPUT VOLTAGE CONTROL (terminal 2) and terminal 1.

2. Connect a CURRENT CONTROL resistor from the NEGATIVE REMOTE OUTPUT VOLTAGE CONTROL (terminal 2) to the load as shown in the above diagram. The CURRENT CONTROL resistance should be numerically equal to (in ohms) or greater than the ohms/volt ratio specified for this unit in the discussion on REMOTE OUTPUT VOLTAGE CONTROL terminals in Section A. (e.g. for a 330 ohms/volt model use a 500 ohm pot.).

3. Choose a CURRENT SENSING resistance sufficient to produce a 1 volt drop at maximum desired output current. Connect this CURRENT SENSING resistor in series with the external load R_L and the NEGATIVE OUTPUT (terminal 4).

   Current Sensing Res. = 1 / max. output amps. desired

SECTION 4
MAINTENANCE AND REPAIRS

4-1 GENERAL INFORMATION. -

The performance of this Power Supply will in a sense be dependent on the collective performance of all of its components. Kepco chooses and tests these components to provide long life and trouble-free operation of the unit.

However, if component failure should occur, it is recommended that troubleshooting be handled by personnel familiar with transistor circuitry, preferably with experience in feedback regulator design. The essential regulating circuitry is a closed-loop DC servo system. The same circuit sensitivity which enables a high degree of regulation to be obtained also increases the susceptibility of the circuit to interrelated functional disorders if the equipment is improperly serviced.

....REFERENCE MATERIAL. -

The Instruction Manual furnished with the Power Supply is identified with the serial number of the unit, assuring that the information it contains is correct and current for the unit to which it applies. The following reference material is provided in the Manual to aid in troubleshooting and repairs:

1. Large schematic diagrams showing essential voltage measurements and component values.

2. Parts location photos or drawings.

3. Parts lists identifying all replacement parts with description and specifications, and the name and manufacturer's part number of at least one replacement source for each item.

....FACTORY REPAIRS. -

If it becomes necessary or desirable to return the equipment to KEPCO for servicing, it should not be shipped to the factory without the sender having prior authorization and shipping instructions. The inclusion of detailed information with the unit, or in correspondence preceding its return to the factory will greatly expedite completion of repairs and return of the equipment to the sender.

In any correspondence with the factory about this Power Supply, the model and serial numbers should always be included.

4-2 MAINTENANCE. -

Under normal operating conditions, only a minimum of maintenance may be required.

1. Fan Assemblies. - If the unit is equipped with muffin-type fan assemblies (black impeller, motor enclosed in hub), this type is permanently lubricated by the manufacturer and does not require relubrication. The open frame type of motor may be lubricated lightly every six months.

2. Brushes. - In units that contain a variable transformer, the brush assembly should not as a rule ever require maintenance or replacement. If it is desired to clean the commutator track, use only a soft cloth moistened lightly with an electrical cleaner (not a solvent). Never use any type of abrasive material on the track.

3. Vacuum Tube Replacement. - Vacuum tubes may be replaced as required when they become defective, or at arbitrary intervals of either life or use. Unless specifically indicated, tubes may be replaced individually and need not be replaced in sets or groups.

4. Performance Tests. - If the unit is to be tested and measured to determine its performance with respect to Regulation, Ripple, etc., the section in the Manual on Regulation Measurements should be read, and the recommended procedures contained therein, or their equivalent, should be followed to aid in obtaining accurate test measurements.

...PRELIMINARY TROUBLESHOOTING CHECKS. - Before proceeding with any extensive electrical troubleshooting, it is advisable to carefully check the Supply for any operational or mechanical disorders.

1. Check for broken, loose, or shorted terminals, wires, and connections; loose connectors, open or loose fuses, tripped circuit breakers, etc. Check all internal as well as external fuses.

2. If the malfunction relates to an overtemperature condition, check to see that the fans work properly and that the openings weren't blocked during operation. On units with overtemperature protection be sure to allow enough time for the thermostat switch to cool and to restore to normal position.

3. Check all operational functions and controls for proper settings. For example, on units with automatic current limiting, a low current setting can, under certain conditions, have the effect of limiting the output voltage, which may appear to be a malfunction. Check to determine whether any internal adjustments may have been reset for any reason, and left at a setting that is incorrect.

4-3 NOTES ON TRANSISTOR SERVICING TECHNIQUES.

....MECHANICAL.

1. A transistor should not be disconnected from, or connected to its circuit while voltage is still present in the circuit.

2. When a soldering iron must be used to remove or install a transistor, or a diode, the heat of the iron while it is being applied to the terminals will almost certainly damage the component unless precautions are taken to prevent it:

   a. When soldering, always apply a temporary "heat sink" to the leads between the iron and the semiconductor to drain off the heat travelling up the lead.

      Note: Pliers are often used for this purpose - be sure they are effective; e.g., flat blade "duck-bills" are good, narrow blade or "toothed" long-nose pliers may be poor.

   b. Solder quickly, so as to limit the application of heat to the briefest possible duration. In this respect use a good iron with proper and sufficient heat for the connection. An iron of too low heat tends to require longer application.

3. When removing or installing a transistor or a diode which has its case connected to one of its elements, be sure to preserve the arrangement of any insulating materials, such as mica washers or bushings.

4. When installing plug-in transistors which have flexible leads, be sure to align the leads and socket pins properly; especially in the "universal" sockets which were designed to accommodate more than one lead pattern.

....ELECTRICAL.

1. Transistor Testers. - Transistor checking instruments, either commercial types or those of local design, may be used. These are usually effective and practical, but not in every case, depending on many circumstances including the accessibility of the unit under test, and the range of the instrument.

2. In-Circuit Analysis. - In some cases the condition of a transistor may be determined by observing certain of its electrical characteristics while it is operating in the circuit. These may range from voltage readings to AC analysis with an oscilloscope.

....ELECTRICAL. (continued)

3. Ohmmeter Check. - Transistor failures of a more complete nature such as shorted or open junctions may be easily detected by test with an ohmmeter. However, some precautions are necessary:

   a. Use the low ohms scale only (Rx1), and then only if the source voltage of the meter (battery) is not more than 2 volts. The use of a higher range or one with high battery voltage may give erroneous indications and might even damage a transistor.

   b. The "common: or black terminal on most ohmmeter instruments is the Positive terminal of the ohmmeter battery, not negative as is commonly believed. When checking semiconductors with an ohmmeter it is usually necessary to know the polarity of this voltage in order to interpret the readings obtained. Some manufacturers of ohmmeters are now indicating this polarity on their meters.

   c. An ohmmeter test between any two terminals of a transistor indicates by the needle deflection whether it is conducting ohmmeter current between those two terminals; and the amount of deflection is related to the amount of this current and to the voltage drop developed across the junction. The actual reading in ohms is not as significant as are other conclusions from the readings. With the polarity of the meter applied as a forward bias to either the base-emitter or base-collector junction, forward current should flow with the needle deflecting on the order of 5-50 ohms; with the polarity reversed in either case, only leakage current flows with little or no perceptible deflection. In both cases the apparent ratio between readings of opposite applied polarity should be on the order of at least 100 to 1. A reading between emitter and collector should be high in both directions.

   d. When an ohmmeter is used to test a transistor that is still in the circuit, the parallel effects of other components in the circuit should be taken into consideration.

4. Substitution. - The above procedures are very often used to localize a trouble down to a circuit area or to one component with final proof dependent on substituting a known good component. It is possible for one bad transistor in a circuit to "pull" another one with it. When a transistor is found to be defective, it should not be replaced before all others have been checked, including those which would appear to be not directly associated in the circuit with the defective one.

....DIODES.

1. Most of the preceding material on transistors is applicable to diodes, except that diodes are two terminal devices consisting of a single junction. The ratio of "front to back" readings on an ohmmeter should similarly be on the order of 100 to 1.

2. When replacing diodes, be sure to observe the proper polarity:

   a. The "triangle" of a diode symbol represents the anode and "points" in the direction of forward conduction under conditions of applied forward bias.

   b. Diodes are marked with their polarity in terms of their output and the cathode is marked positive (+).

....ZENER DIODES.

1. Zener diodes may be checked with an ohmmeter provided they are of a single junction type. Double anode types have a common cathode which is not brought out to a terminal. Thus, whichever polarity of the ohmmeter is applied to the two anode terminals, it will read a high resistance reverse bias in both directions. A short however, can be detected. Manufacturers are not yet consistent in their marking of polarity on Zeners; before disconnecting a Zener, be sure to note its markings with respect to the terminals to which it is connected.

2. A positive test of a Zener diode is to measure the voltage across it while it is in operation. If instrumentation is available, the voltage regulation across its terminals should be measured and compared to its ratings.

4-4 POWER SUPPLY MEASUREMENTS. -

....DEFINITIONS -

Line Regulation. - Stated in percentage of the output voltage, Line Regulation specifies the maximum amount that the output voltage will change as the result of a specified change in line voltage, with the load maintained at a constant value.

Load Regulation. - Stated in percentage of the output voltage (or in actual value) specifies the maximum amount that the output voltage will change as the result of a specified change in output load current, with the line voltage maintained at a constant value.

MEASURING REGULATION. -

Load Regulation and other performance characteristics can be measured at any point in a system. However the results obtained will apply only to the specific point at which they are measured, and may differ from what is specified for the output of the Supply. If it is desired to measure or to verify the performance of the Supply itself, the measurements should be made at the terminals on the Supply, using instrumentation and procedures that are capable of measuring with the desired accuracy.

As an example, consider a Kepco Model SC 32-5, 32 volt/5 ampere Supply which has 0.01% regulation. At 32 volts, the output voltage at the terminals will not change more than 3.2 millivolts (0.0032 v) for a change from no-load to full-load. If the load were to be connected by only 12 inches of #12 gage wire in each lead, at full-load the total drop across the resistance in these wires would amount to 16 millivolts, equivalent to 5 times the voltage change within regulation. The regulation measured at the load would be 0.05% while at the terminals it would measure 0.01%.

Instrumentation. -

1. Line Voltage. - By definition, load regulation is specified, and measured with a condition of constant line voltage. A constant voltage transformer or other source of constant AC is required. If the AC source is also adjustable it can be used to vary or step the line voltage input for measuring Line Regulation.

2. Load. - An accurate full-load is required, preferably one that can be conveniently applied, or stepped on and off by some switching means.

3. Measurement. - Any instrument may be used that is capable of measuring both the absolute value of the output voltage, and the small magnitude of change in the output voltage occurring as the line or load changes are applied.

a. A differential voltmeter may be used; or a power supply analyzer such as the Kepco Regulation Analyzer Model 901C which gives measurements directly in percentage.

b. A DC coupled oscilloscope may be used, if a suitable auxiliary DC voltage is available to buck-out the voltage under test so that only the net change can be measured. The buck-out voltage must be at least equal in magnitude to, and have a greater order of regulation than the voltage under test.

Procedure. -

1. On Supplies that have more than one set of output terminals (most Kepco Supplies have terminals on the front and the rear) measurement can be made at either set, except on those Supplies where the regulation is specified for one particular set of terminals. In any case, both the load and the measuring instrument should be connected to the same terminals.

2. To avoid terminal losses giving erroneous measurements, on each output terminal connect the load to one end and the instrument to the other end of a short length of #14 bus wire looped around the terminal, as shown in Fig. 4-1.

3. The Supply should not be set up for Remote Error sensing where this facility is provided. Error Sensing jumpers to the output terminals, where employed, should be securely in place.

....RIPPLE MEASUREMENT.

Any AC ripple component present in the DC output of a properly functioning Power Supply will be small in magnitude, on the order of millivolts. It is usually stated in the specifications for the Supply either in millivolts RMS or in percentage (in RMS) of the output voltage. Because of its small magnitude, a sensitive instrument must be used to measure the ripple, and care must be exercised in order to obtain accurate readings.

1. Be certain that the input to the measuring instrument contains a blocking capacitor to isolate the DC voltage from the ripple component, and that the DC voltage rating of the capacitor is sufficiently high for the DC output voltage that will be applied.

2. Some rectifier types of AC meters do not contain a DC blocking capacitor, and DC current will pass through the rectifier to the meter movement. In such cases, or where the internal capacitor does not have a high enough DC rating, a 0.1 μf capacitor (with sufficiently high DCWV) connected in series with the high side of the input will insure isolation of the DC from the ripple.

3. Interconnecting leads between the Power Supply and the instrument should be short and preferably shielded to prevent stray AC pickup. When using a measuring instrument that is connected to the same power line, be certain to have good connections in the interconnecting leads to avoid the introduction of a ground loop.

CONNECTIONS FOR REGULATION MEASUREMENT

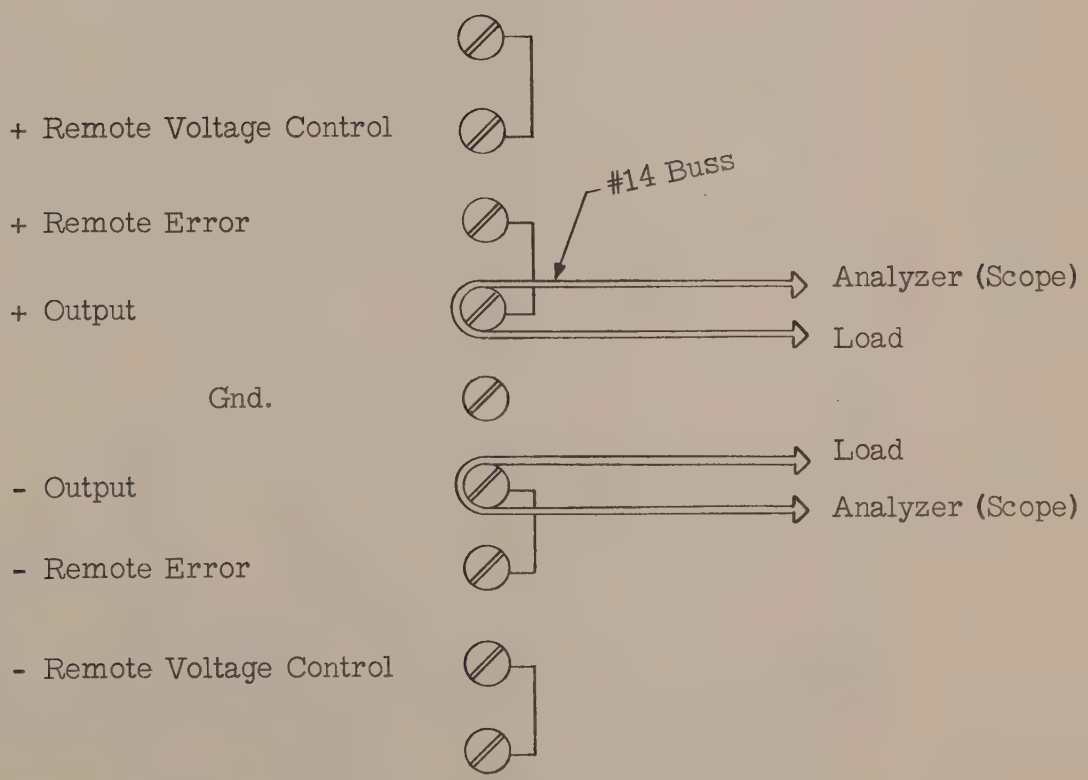


Fig. 4-1 Connections for Measuring Regulation

Schematic Part No.	Kepco Part No.	Description	Specifications	Mfr.	Mfr's. No.
B201, 202	148-0006	Motor		Barber-Colman	KYAF764-1
		Capacitors:			
C201, 202	117-0159	Electrolytic, Can Type	4.2 K µf 50 v +100, -10%	Industrial Cond.	1B913RRB
C203	117-0087	Ceramic	0.1 µf 500 v + 80, -20%	Sprague	41C92
C204	117-0107	Mylar	0.22 µf 200 v 20%	Good-All	620S22402W
C205	117-0163	Ceramic	0.05 µf 600 v 20%	Sprague	36C142A1
C206	117-0114	Electrolytic, Pigtail Type	350 µf 50 v +100, -10%	Industrial Cond.	1B844
C207	117-0156	Electrolytic, Pigtail Type	500 µf 12 v +100, -10%	Industrial Cond.	21RM500
C208	117-0121	Electrolytic, Pigtail Type	100 µf 12 v +100, -10%	Industrial Cond.	1B1091RM
C210	117-0140	Electrolytic, Pigtail Type	100 µf 150 v + 50, -10%	Industrial Cond.	10B916RM
C211	117-0087	Ceramic	0.1 µf 500 v + 80, -20%	Sprague	41C92
		Rectifiers:			
CR201, 202	124-0086	Silicon, Stud Type		Intern'l Rectifier	6 F20K
CR203-207	122-0007	Germanium, Pigtail Type		General Electric	1N91
CR208, 209	124-0028	Silicon, Pigtail Type		Automatic Mfg.	PT-5
F101	141-0003	Fuse, Instantaneous	4 a 250 v	Bussmann	MTH-4
F201, 202	141-0005	Fuse, Instantaneous	1/4 a 250 v	Bussmann	AGC 1/4
M101	135-0118	Meter*	4 a dc 2-1/2"	Weston	1721
M102	135-0107	Meter*	20 v dc 2-1/2"	Weston	1721

*(appl. only to Model SC 18-4M)

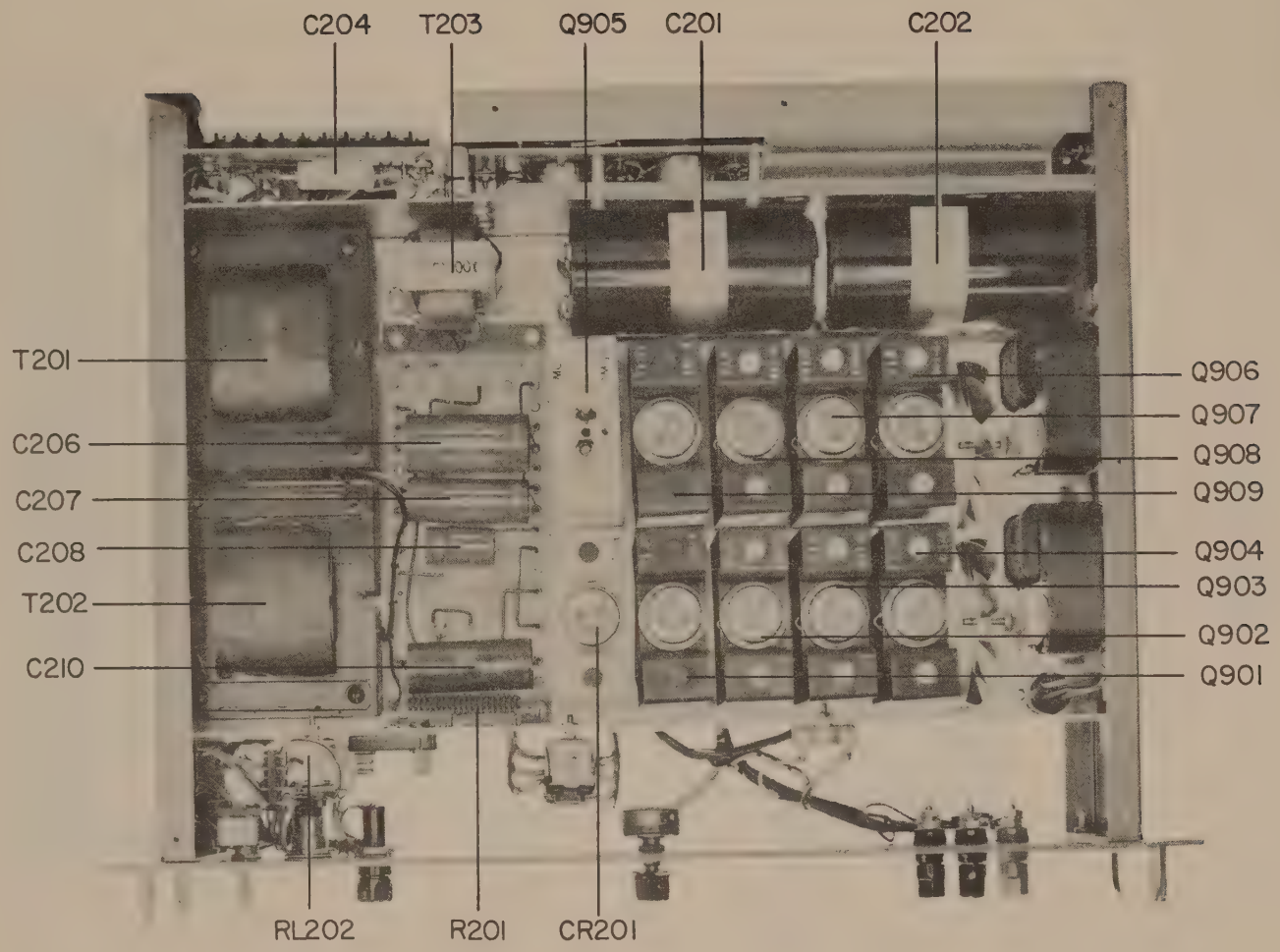
Schematic Part No.	Kepco Part No.	Description	Specifications	Mfr.	Mfr's. No.
PL101	153-0024	Pilot Light, Neon		General Elec.	NE-51
Q201	119-0022	Transistor, PNP		Tung-Sol	2N382
Q901-909	119-0016	Transistor, PNP		Delco	2N441
		Resistors:			
R101	115-0553	Variable, Composition	20 K ohm 2 w 10%	Allen-Bradley	JA1H10CP203UZ
R201	115-0617	Power, Precision	200 ohm 50 w 3%	Dale Products	RH-50
R202	115-0050	Fixed, Molded	10 ohm 2 w 10%	Allen-Bradley	HB1001
R203	115-0608	Fixed, Molded	470 ohm 1/2 w 10%	Allen-Bradley	EB4711
R204	115-0622	Fixed, Molded	39 ohm 2 w 10%	Allen-Bradley	HB3901
R205	115-0373	Fixed, Molded	470 ohm 2 w 10%	Allen-Bradley	HB4711
R206	115-0543	Fixed, Molded	150 ohm 1/2 w 10%	Allen-Bradley	EB1511
R207	115-0577	Fixed, Power, Strip	150 ohm 20 w 5%	Ward Leonard	20S150
R208	115-0502	Fixed, Molded	10 ohm 1/2 w 10%	Allen-Bradley	EB1001
R209-211	115-0718	Fixed, Molded	47 ohm 1/2 w 10%	Allen-Bradley	EB4701
R901-908	115-0517	Fixed, Power, Axial	1.5 ohm 3 w 5%	Ward Leonard	3X1.5
RL201, 202	140-0018	Relay	DPDT	Line Electric	MK-1027
S101	127-0013	Switch, Toggle	DPDT	Cutler-Hammer	8825-K5
S201, 202	127-0083	Switch, Thermostat	N. O.	Chatham Cont.	DRSCCRP73C

Schematic Part No.	Kepco Part No.	Description	Specifications	Mfr.	Mfr's. No.
T201	100-1049	Transformer		Kepco Magnetics	100-1049
T202	100-1048	Transformer		Kepco Magnetics	100-1048
T203	100-1039	Transformer		Kepco Magnetics	100-1039

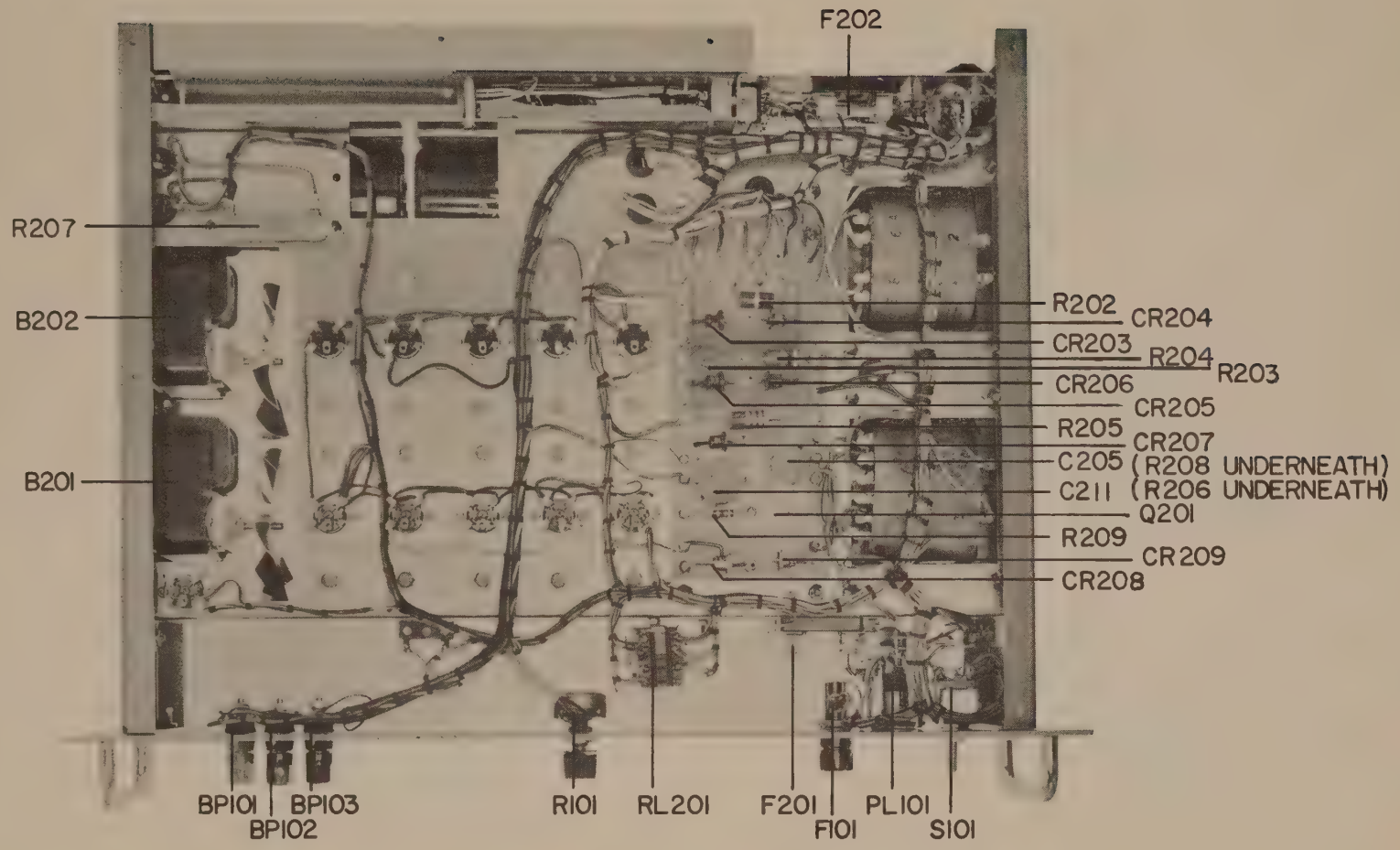
Schematic Part No.	Kepco Part No.	Description	Specifications	Mfr.	Mfr's. No.
C1	117-0128	Capacitor, Mylar	0.4 µf 200 v 10%	Hopkins Eng.	P42M
CR1	122-0007	Rectifier, Germanium, Pigtail Type		General Elec.	1N91
Q1	119-0007	Transistor, NPN		General Trans.	2N35
Q2	119-0022	Transistor, PNP		Tung-Sol	2N382
Q3	119-0024	Transistor, NPN		General Trans.	GT1092
		Resistors:			
R1	115-0489	Fixed, Molded	10 K ohm 1/2 w 10%	Allen-Bradley	EB1031
R2	115-0558	Fixed, Molded	680 ohm 1/2 w 10%	Allen-Bradley	EB6811
R3	115-0625	Variable, Composition	500 ohm 2 w 10%	Allen-Bradley	JA1L040S501UZ
R4	115-0334	Variable, Composition	5 K ohm 2 w 10%	Allen-Bradley	JA1L040S502UZ
R5	115-0883	Fixed, Molded	390 ohm 1/2 w 5%	Allen-Bradley	EB3915
R6, 7, 8, 13	115-0467	Fixed, Molded	4.7 K ohm 1/2 w 10%	Allen-Bradley	EB4721
R9	115-0371	Fixed, Molded	220 ohm 1/2 w 10%	Allen-Bradley	EB2211
R10	115-0560	Fixed, Molded	2.7 K ohm 1/2 w 10%	Allen-Bradley	EB2721
R11	115-0872	Fixed, Molded	270 ohm 2 w 5%	Allen-Bradley	HB2715
R12	115-0571	Variable, Composition	2.5 K ohm 2 w 10%	Allen-Bradley	JA1L040S252UZ
R14	115-0884	Fixed, Molded	110 ohm 1/2 w 5%	Allen-Bradley	EB1115
R15	115-0631	Fixed, Molded	220 ohm 1 w 10%	Allen-Bradley	GB2211
RD1	121-0013	Reference Diode		Hoffman	RS6
RD2	121-0012	Reference Diode		Hoffman	1N1773

FIELD REPLACEMENT LIST

Kepco Part No.	Description	Recommended Replacement MFR.	MFR. No.
119-0016	Transistor, PNP	Delco	2N174
119-0020	Transistor, PNP	RCA	2N398A
119-0022	Transistor, PNP	Tung Sol	2N1707
		Texas Instrument	2N404
119-0024	Transistor, NPN	General Inst.	2N1605
		RCA, General Elec.	2N388
		Texas Instrument	
		Sylvania, Texas Instrument	2N1308
119-0034	Transistor, PNP	Delco	2N1172
		Hughes	2N1131A
119-0035, 0036,0037	Transistor, PNP	Motorola	2N1167
		Clevite	CTP 3553
119-0038	Transistor, NPN	Transitron	ST29
119-0048	Transistor, Unijunction	General Electric	2N1671A
119-0049	Transistor, PNP	Delco	2N669
119-0054	Transistor, NPN	General Electric	2N338
			2N336A
119-0055	Transistor, PNP	Hughes	2N1131A
119-0056	Transistor, NPN	General Electric	2N336A
119-0057	Transistor, PNP	Delco	DTG-1200
119-0059	Transistor, NPN	RCA	2N3053
119-0060	Transistor, NPN	RCA	2N3054
119-0061	Transistor, NPN	RCA	2N3055
119-0065	Transistor, PNP	Hughes	2N3225
119-0067	Transistor, PNP	Delco	DTG-2400
119-0068	Transistor, NPN	RCA	40250
119-0069	Transistor, NPN	RCA	40251
119-0070	Transistor, NPN	RCA	2N3442

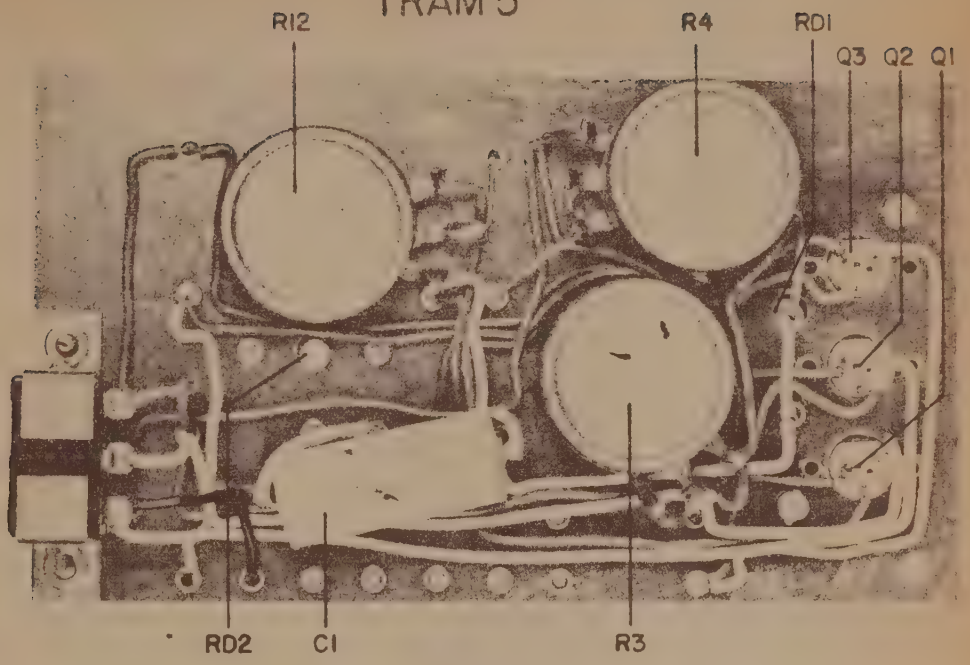

C204
T203
Q905
C201
C202
T201
C206
C207
C208
T202
C210
Q906
Q907
Q908
Q909
Q904
Q903
Q902
Q901
RL202
R201
CR201

SC-18-4 TOP

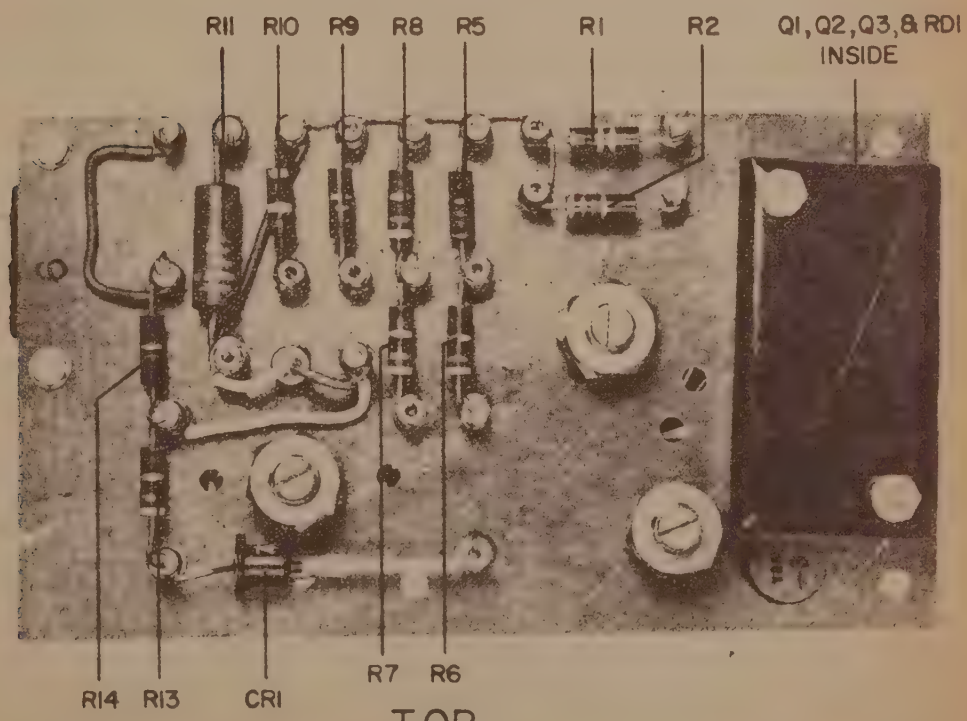


SC-18-4 BOTTOM

TRAM 5

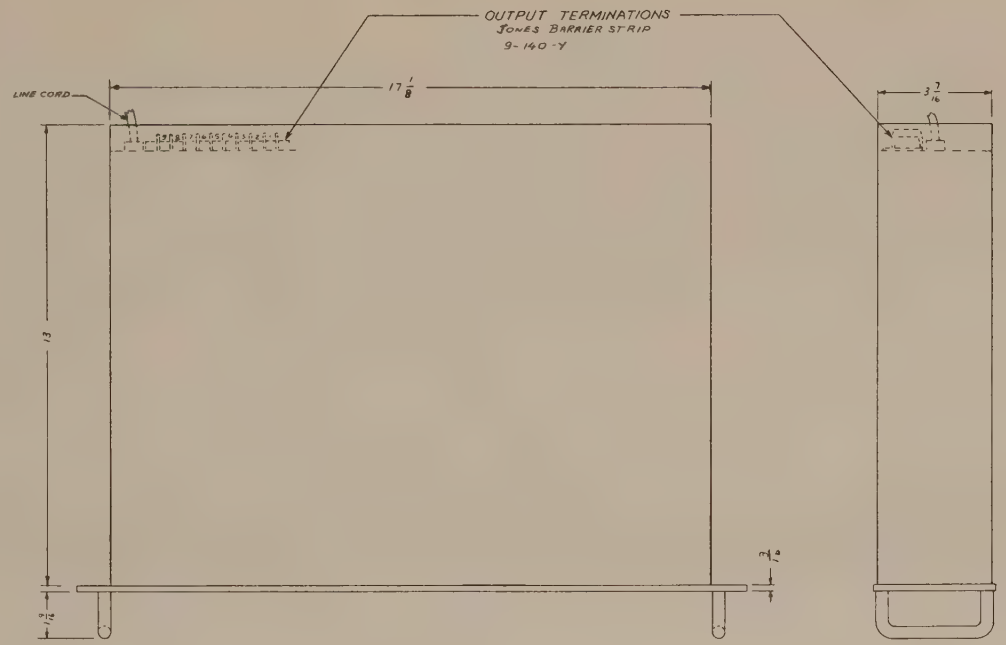


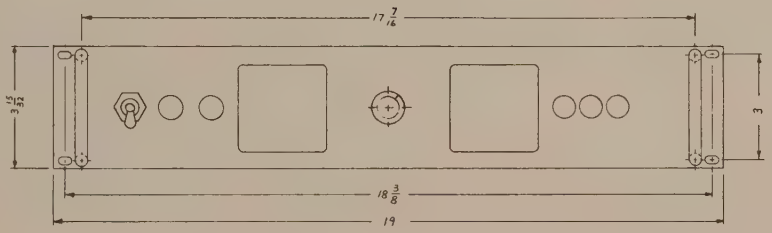
BOTTOM



TOP

C M00595





NOTE:
THIS DRAWING ALSO USED FOR THE FOLLOWING.

SC-32-0.5	SC-18-4
SC-32-1	SC-36-2
SC-32-1.5	SC-3672-1
SC-32-2.5	

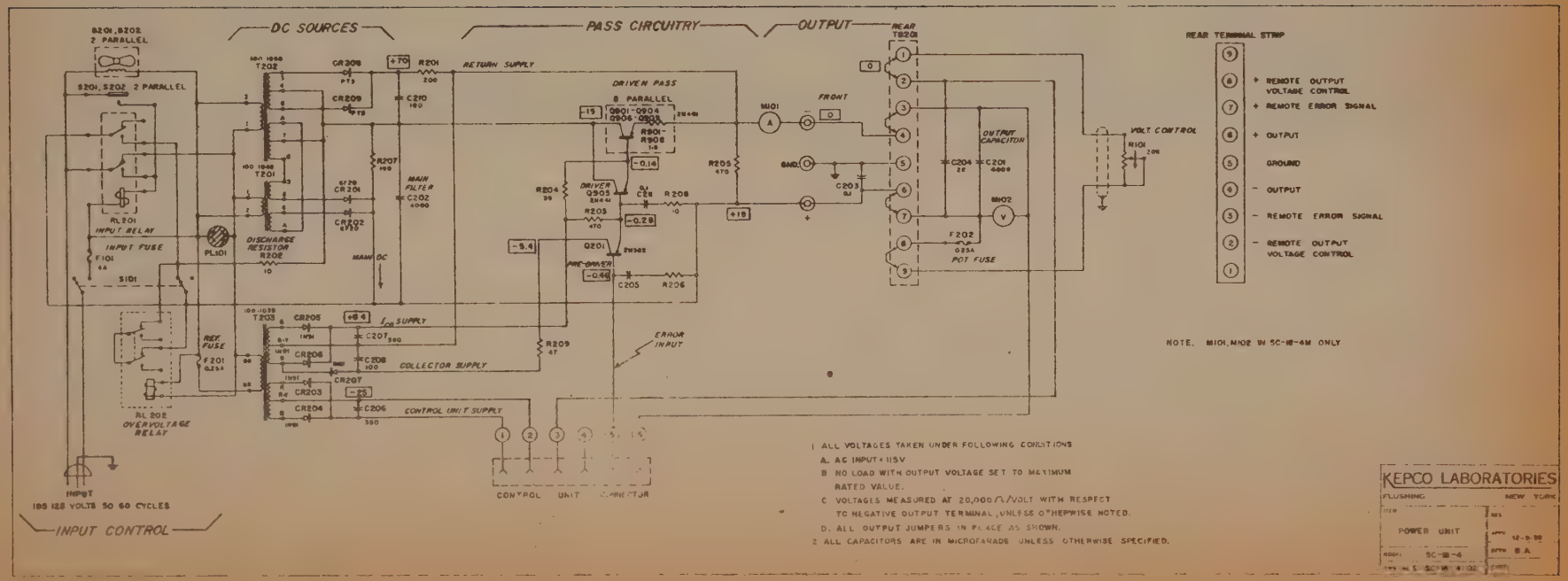
TOLERANCE UNLESS OTHERWISE SPECIFIED · FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1/2°

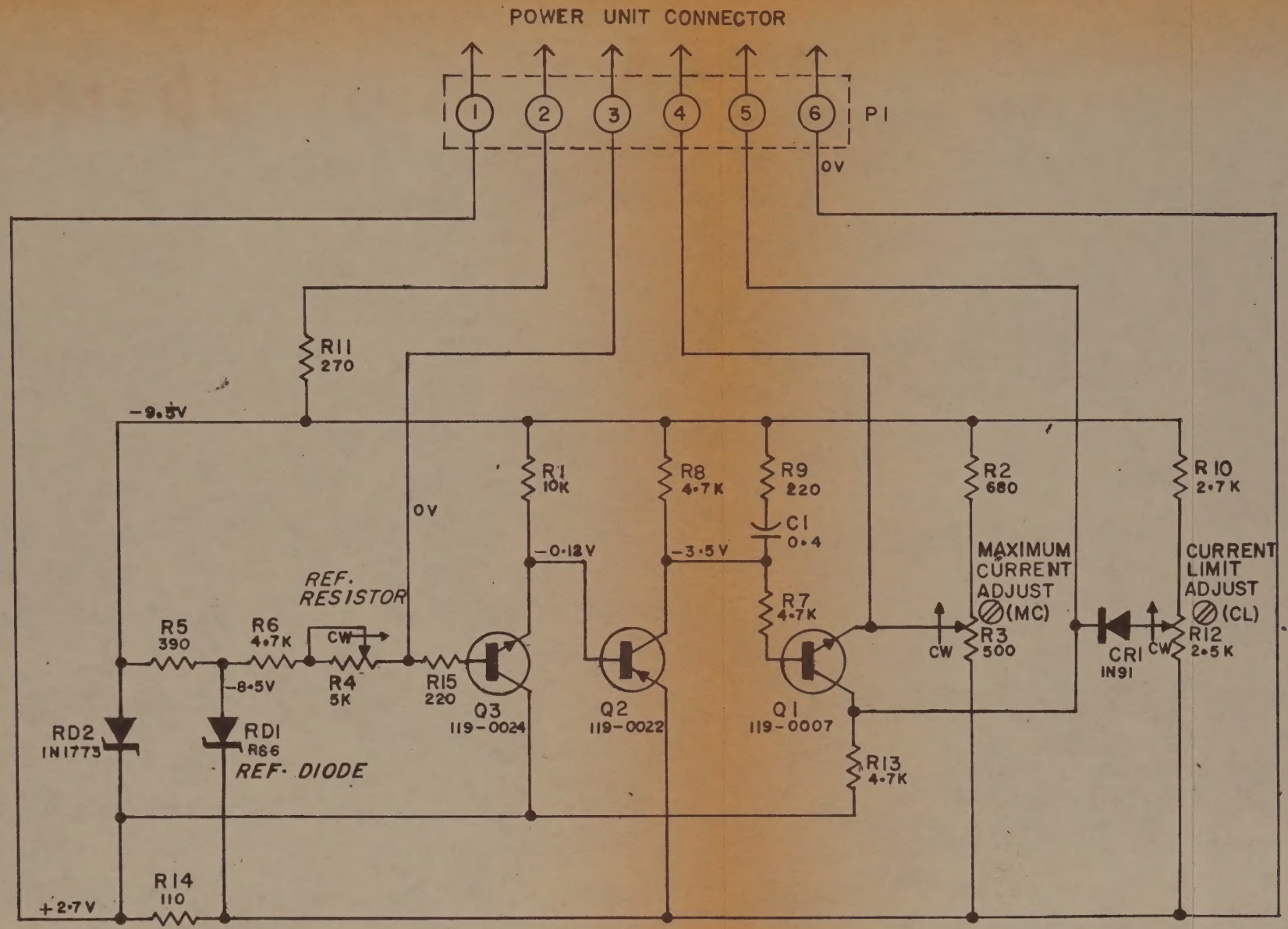
KEPCO INC.
FLUSHING, N.Y.

TITLE: OUTLINE DRAWING

DRAWN	CHECKED	APPROVED	DATE
B.A.	GB		12-7-59
MODEL NO. SC-3-1/2 SERIES		PART NO.	SCALE HALF

DWG. NO. C M00595


DC SOURCES
PASS CIRCUITRY
OUTPUT
INPUT CONTROL
Q201, Q202 2 PARALLEL
Q201, Q202 2 PARALLEL
T202
T201
T203
CR208
CR209
CR201
CR202
CR205
CR206
CR207
CR203
CR204
+70
+8.4
-15
-6.5
R201
200
C210
100
R207
100
MAIN FILTER
C202
4000
RETURN SUPPLY
DRIVEN PASS
8 PARALLEL
Q901-Q904
Q906-Q909
2N4401
R901-R908
1Ω
-0.14
R205
470
R204
39
DRIVER
Q905
2N4401
R203
470
-0.28
R208
10
-5.4
Q201
2N3402
PRE-DRIVER
-0.46
C205
R206
R209
47
ERROR INPUT
+18
MI01
FRONT
GND.
C203
.01
MI02
C204
20
C201
4000
OUTPUT CAPACITOR
R101
20K
VOLT CONTROL
F202
.025A
POT FUSE
REAR
TB201
REAR TERMINAL STRIP
+ REMOTE OUTPUT VOLTAGE CONTROL
+ REMOTE ERROR SIGNAL
+ OUTPUT
GROUND
- OUTPUT
- REMOTE ERROR SIGNAL
- REMOTE OUTPUT VOLTAGE CONTROL
NOTE. MI01, MI02 IN SC-18-4M ONLY
INPUT RELAY
RL201
INPUT FUSE
F101
6A
S101
DISCHARGE RESISTOR
R202
10
PL101
MAIN DC
REF FUSE
F201
0.25A
RL202
OVERVOLTAGE RELAY
I_{CR} SUPPLY
C207
350
COLLECTOR SUPPLY
C208
100
CONTROL UNIT SUPPLY
C206
350
INPUT
105-128 VOLTS 50-60 CYCLES
CONTROL UNIT CONNECTOR
1 ALL VOLTAGES TAKEN UNDER FOLLOWING CONDITIONS
A. AC INPUT = 115V
B NO LOAD WITH OUTPUT VOLTAGE SET TO MAXIMUM RATED VALUE.
C VOLTAGES MEASURED AT 20,000Ω/VOLT WITH RESPECT TO NEGATIVE OUTPUT TERMINAL, UNLESS OTHERWISE NOTED.
D. ALL OUTPUT JUMPERS IN PLACE AS SHOWN.
2 ALL CAPACITORS ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
KEPCO LABORATORIES
FLUSHING NEW YORK
POWER UNIT
SC-18-4
12-9-58
B.A.



NOTE:

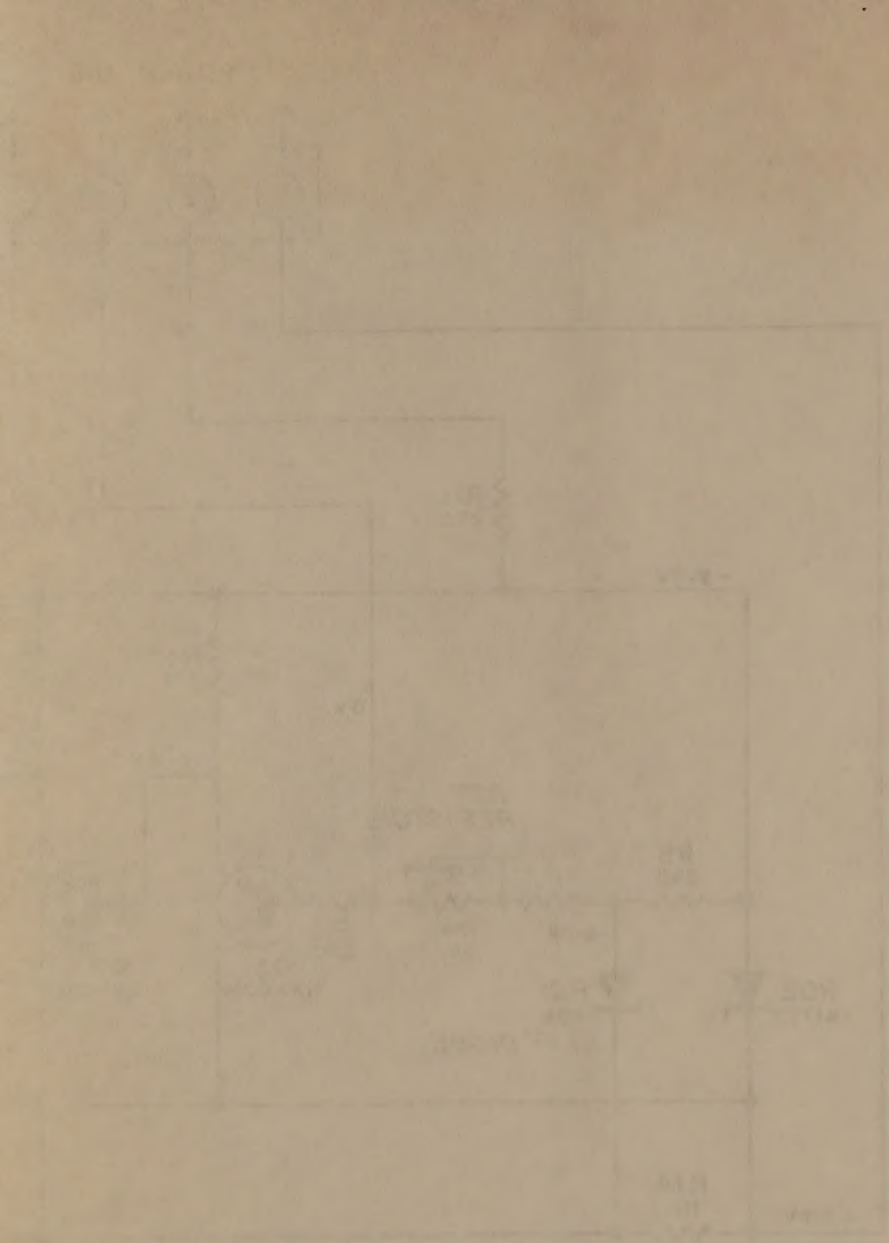
1- ALL VOLTAGES TAKEN UNDER CONDITIONS SPECIFIED ON MAIN SCHEMATIC.

2- ALL CAPACITORS ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED; RESISTANCE IN OHMS, K= 1000

KEPCO INC.
FLUSHING, N.Y.

TITLE			
CONTROL UNIT			
DRAWN	CHECKED	APPROVED	DATE
E. A.	JAB.	K.K.	3-31-60
MODEL NO.		PART NO.	SCALE
TRAM 5			
DWG. NO. BM01899			

OBSOLETE 5-10-62



CORRECTION SHEET FOR INSTRUCTION MANUAL

MATERIAL AFFECTED	CORRECTION
Power Unit Schematic	Add the following: 1. Resistor R210, 47 Ω; from (+) Remote Error Signal to (+) Output Terminal. 2. Resistor R211, 47 Ω; from (-) Remote Error Signal to (-) Output Terminal. Physical Location: back of rear Output Terminal Strip.
PARTS LOCATION PHOTO, CONTROL UNIT, TRAM 5	Show R 15 mounted to left of R 13 in bottom view.

KEPCO, INC. • 131-38 SANFORD AVENUE • FLUSHING, N.Y. 11352 • (212) 461-7000 • TWX #710-582-2631 • Cable: KEPCOPOWER NEWYORK

#146-0045 4/67